April 4, 1867.

Lieutenant-General SABINE, President, in the Chair.

The following communications were read:—

I. "Researches on Gun-cotton.—Second Memoir. On the Stability of Gun-cotton." By F. A. Abel, F.R.S., V.P.C.S. Received March 9, 1867.

(Abstract.)

The results of the many observations which had been instituted prior to 1860 upon the behaviour of gun-cotton when exposed to diffused or strong daylight, or to heat, although they agree generally with those of the most recent investigations on the subject, as far as relates to the nature of the products obtained at different stages of its decomposition, cannot be regarded as having a direct bearing upon the question of the stability of gun-cotton produced by strictly pursuing the system of manufacture prescribed by von Lenk, inasmuch as it has been shown that the products formerly experimented upon by different chemists varied very considerably in composition.

The investigations recently published by Pélouze and Maury*, into the composition of gun-cotton, and the influence exerted by light and heat upon its stability, are described as having been conducted with gun-cotton prepared according to von Lenk's system. The general conclusion arrived at by those chemists with reference to the latter branch of the subject was to the effect that the material is susceptible of spontaneous decomposition, under conditions which may possibly be fulfilled in its storage and application to technical and warlike purposes; and the inference is drawn, partly from the results of earlier investigators, and partly from the exceptional behaviour of one or two specimens, that gun-cotton is liable to explode spontaneously at very low temperatures when stored in considerable quantities.

It has been shown, in the memoir on the Manufacture and Composition of Gun-cotton, published last year†, that modifications in the processes of conversion and purification, which appear at first sight of very trifling nature, exert most important influences upon the composition and purity of the product. Gun-cotton of quite exceptional character has been discovered, in several instances, among samples received from Hirtenberg and among the first supplies obtained from Stowmarket; other exceptional products have also been produced by purposely modifying, in several ways, the system of manufacture as pursued at Waltham Abbey. The very considerable difference exhibited between some of these and the ordinary products in their behaviour under equal conditions of exposure to heat and light, affords good grounds for the belief that the attainment of certain exceptional results, upon which the conclusions of Pélouze and Maury's report

* Comptes Rendus.

† Trans. Royal Society.

condemnatory of gun-cotton, have been principally founded, are to be ascribed to such variations in the nature of the material operated upon.

Very numerous and extensive experiments and observations have been carried on during the last four years at Woolwich, both with small and large quantities of gun-cotton, for the purpose of completely investigating the conditions by which the stability of this substance, when under the influence of light and heat, may be modified, and with the view of ascertaining whether results recently arrived at in France apply to gun-cotton as manufactured in this country.

The principal points which have been established by the results arrived at in these investigations may be summed up as follows:—

1. Gun-cotton produced from properly purified cotton, according to the directions given by von Lenk, may be exposed to diffused daylight, either in the open air or in closed vessels, for very long periods without undergoing any change. The preservation of the material for $3\frac{1}{2}$ years under those conditions has been perfect.

2. Long-continued exposure of the substance in a condition of ordinary dryness to strong daylight and sunlight produces a very gradual change in gun-cotton of the description defined above; and therefore the statements which have been published regarding the very rapid decomposition of gun-cotton when exposed to the sunlight do not apply to the nearly pure trinitrocellulose obtained by strictly following the system of manufacture now adopted.

3. If gun-cotton in closed vessels is left for protracted periods exposed to strong daylight or sunlight in a damp or moist condition, it is affected to a somewhat greater extent; but even under these circumstances the change produced in the gun-cotton by several months' exposure is of a very trifling nature.

4. Gun-cotton which is exposed to sunlight until a faint acid reaction has become developed, and is then immediately afterwards packed into boxes which are tightly closed, does not undergo any change during subsequent storage for long periods. (The present experience on this head extends over $3\frac{1}{2}$ years.)

5. Gun-cotton prepared and purified according to the prescribed system, and stored in the ordinary dry condition, does not furnish any indication of alteration, beyond the development, shortly after it is first packed, of a slight peculiar odour and the power of gradually imparting to litmus, when packed with it, a pinkish tinge.

6. The influence exercised upon the stability of gun-cotton of average quality, as obtained by strict adherence to von Lenk's system of manufacture, by prolonged exposure to temperatures considerably exceeding those which are experienced in tropical climates is very trifling in comparison with the results recently published by Continental experimenters relating to the effects of heat upon gun-cotton; and it may be so perfectly counteracted by very simple means which in no way interfere with the essential qualities

of the material, that the storage and transport of gun-cotton presents no greater danger, and is, under some circumstances, attended with much less risk of accident than is the case with gunpowder.

7. Perfectly pure gun-cotton, or trinitrocellulose, resists to a remarkable extent the destructive effects of prolonged exposure to temperatures even approaching 100° C.; and the lower nitro- products of cellulose (soluble gun-cotton) are at any rate not more prone to alteration when pure. The incomplete conversion of cotton into the most explosive products does, therefore, not of necessity result in the production of a less perfectly perfectly permanent compound than that obtained by the most perfect action of the acid mixture.

8. But all ordinary products of manufacture contain small proportions of organic (nitrogenized) impurities of comparatively unstable properties, which have been formed by the action of nitric acid upon foreign matters retained by the cotton fibre, and which are not completely separated by the ordinary, or even a more searching process of purification.

It is the presence of this class of impurity in gun-cotton which first gives rise to the development of free acid when the substance is exposed to the action of heat; and it is the acid thus generated which eventually exerts a destructive action upon the cellulose-products, and thus establishes decomposition which heat materially accelerates. If this small quantity of acid developed from the impurity in question be neutralized as it becomes nascent, no injurious action upon the gun-cotton results, and a great promoting cause of the decomposition of gun-cotton by heat is removed. This result is readily obtained by uniformly distributing through gun-cotton a small proportion of a carbonate,—the sodic carbonate, applied in the form of solution, being best adapted to this purpose*.

9. The introduction into the finished gun-cotton of 1 per cent. of sodic carbonate affords to the material the power of resisting any serious change, even when exposed to such elevated temperatures as would induce some decomposition in the perfectly pure cellulose-products. That proportion affords, therefore, security to gun-cotton against any destructive effects of the highest temperatures to which it is likely to be exposed even under very exceptional climatic conditions. The only influences which the addition of that amount of carbonate to gun-cotton might exert upon its properties as an explosive would consist in a trifling addition to the small amount of smoke attending its combustion, and in a slight retardation of its explosion, neither of which could be regarded as results detrimental to the probable value of the material.

* The deposition of calcic and magnesian carbonates upon the fibre of gun-cotton, either by its long-continued immersion in flowing spring water, or by its subjection to the so-called "silicating" process adopted by von Lenk, produces a similar protective effect, which, however, is necessarily very variable in its extent, as the amount of carbonate thus introduced into a mass of gun-cotton is uncertain; moreover, as it is only loosely deposited between the fibres, the proportion is liable to be diminished by any manipulation to which the gun-cotton may be subjected.

10. Water acts as a most perfect protection to gun-cotton (except when it is exposed for long periods to sunlight), even under extremely severe conditions of exposure to heat. An atmosphere saturated with aqueous vapour suffices to protect it from change at elevated temperatures; and wet or damp gun-cotton may be exposed for long periods in confined spaces to 100° C. without sustaining any change.

Actual immersion in water is not necessary for the most perfect preservation of gun-cotton; the material, if only damp to the touch, sustains not the smallest change, even if closely packed in large quantities. The organic impurities which doubtless give rise to the very slight development of acid observed when gun-cotton is closely packed in the dry condition, appear to be equally protected by the water; for damp or wet gun-cotton, which has been preserved for three years, has not exhibited the faintest acidity. If as much water as possible be expelled from wet gun-cotton by the centrifugal extractor, it is obtained in a condition in which, though only damp to the touch, it is perfectly non-explosive; the water thus left in the material is sufficient to act as a perfect protection, and consequently also to guard against all risk of accident. It is therefore in this condition that all reserved stores of the substance should be preserved, or that it should be transported in large quantities to very distant places. If the proper proportion of sodic carbonate be dissolved in the water with which the gun-cotton is originally saturated for the purpose of obtaining it in this non-explosive form, the material, whenever it is dried for conversion into cartridges, or employment in other ways, will contain the alkaline matter required for its safe storage and use in the dry condition in all climates.

Although some experiments, bearing upon the different branches of inquiry included in this memoir, are still in progress with a view to the attainment of additional knowledge of the conditions which regulate the stability of gun-cotton, it is confidently believed that the results arrived at amply demonstrate that the objections which have been of late revived, especially in France, against the employment of gun-cotton, on the ground of its instability, apply only in a comparatively slight degree to the material produced by strictly pursuing the system of manufacture perfected by von Lenk—that, as far as they do exist, they have been definitely traced to certain difficulties in the manufacture of pure gun-cotton which further experimental research may, and most probably will, overcome—but that, in the meantime, these objections are entirely set aside by the adoption of two very simple measures, against the employment of which no practical difficulties can be raised, and which there is every reason to believe must secure for this material the perfect confidence of those who desire to avail themselves of the special advantages which it presents as an explosive agent.

The nature of the decomposition of gun-cotton when exploded under different conditions is now under investigation by me; and the results arrived at will, I trust, be communicated before long to the Royal Society.